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EVALUATION OF FOUR INERT DUSTS FOR THE PROTECTION OF STORED WHEAT IN KANSAS FROM INSECT ATTACK

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

This report summarizes the results of the first year of a 2- or 3-year test of stored wheat after treatment with two basic types of chemically inert dusts--silica aerogel and diatomaceous earth.

The work was done at the Manhattan, Kans., station of the Stored-Product Insects Research Branch, Market Quality Research Division, Agricultural Research Service (ARS), U.S. Department of Agriculture. The Chemical Unit of the Stored-Product Insects Research and Development Laboratory, Savannah, Ga., made the malathion residue determinations.

Raymond Whitney and Gordon W. Barnes of the USDA's Kansas Agricultural Stabilization and Conservation Service (ASCS) office and Arnold L. Serviss and his associates of the McPherson County ASCS office cooperated in the study.

The following personnel contributed substantially to the subject matter research: Joseph L. Wilson, Warren E. Blodgett, Ralph L. Ernst, and Leon H. Hendricks assisted in conducting the entomological phases of the study; Reba E. Renn, Georgia M. Gurney, Clemmer B. Marcus, Elener Davis, and Ida M. Schneider, Grain Division, Consumer and Marketing Service, and Robert M. Johnson, Dorothy M. Humphrey, Tyler F. Hartsing, Charles E. Holaday, and Doris Baker, Market Quality Research Division, Agricultural Research Service, Beltsville, Md., conducted chemical, moisture, and sedimentation determinations of the grain and milling and baking tests.

NOTICE

Malathion has a legal tolerance of 8.0 p.p.m. when applied to stored grain for insect control and may be used in accordance with label instructions.

At present (1966), a tolerance or exemption from the need for a tolerance has not been established for the use of silica aerogel for the prevention of insect infestation in stored grain. The tests reported herein were exploratory studies to develop information on performance. Silica aerogel treatments should not be used unless a tolerance has been established.

Diatomaceous earth is exempt from the need for a tolerance and may be applied to stored grain for insect control in accordance with label instructions.

GR Instruction 918-6 Aux. 1, dated May 9, 1963, from the Grain Division, Consumer and Marketing Service, provides instructions to licensed grain inspectors for grading grain containing an unknown foreign substance and exceptions for diatomaceous earth. An applicant for inspection, who has grain that contains or appears to contain diatomaceous earth and who wishes to have the grain graded as though it did not contain an unknown foreign substance, may file a written application with the grain inspector for an examination for diatomaceous earth.

Insects Mentioned in This Publication (1)[1]

Angoumois grain moth	Sitotroga cerealella (Olivier)
Cadelle	Tenebroides mauritanicus (Linnaeus)
Common bean weevil[2]	Acanthoscelides obtectus (Say)
Confused flour beetle	Tribolium confusum Jacquelin duVal
Flour beetles	Tribolium spp.
Granary weevil	Sitophilus granarius (Linnaeus)
Indian-meal moth	Plodia interpunctella (Hübner)
Lesser grain borer	Rhyzopertha dominica (Fabricius)
Mediterranean flour moth	Anagasta kuehniella (Zeller)
Rice weevil	Sitophilus oryzae (Linnaeus)
Saw-toothed grain beetle	Oryzaephilus surinamensis (Linnaeus)
Southern cowpea weevil[2]	Callosobruchus maculatus (Fabricius)

[1] Underlined numbers in parentheses refer to Literature Cited at end of publication.
[2] Present approved common name--bean weevil and cowpea weevil, respectively.

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EVALUATION OF FOUR INERT DUSTS FOR THE PROTECTION OF STORED WHEAT IN KANSAS FROM INSECT ATTACK

By G. D. White, W. L. Berndt, J. H. Schesser, and C. C. Fifield[3]

SUMMARY

Four inert dusts were applied to hard red winter wheat for protection from insect attack during storage. Malathion in spray form was used as a standard. This report summarizes the results of the first year of storage after treatment.

The treatments were applied to wheat in standard circular 3,250-bushel metal bins at the McPherson, Kans., ASCS Binsite. The wheat was sampled periodically to determine the insect population trends, moisture content of the wheat, insecticidal residues, depletion of insecticidal effectiveness, and the effect of treatment on the chemical, milling, and baking quality and commercial grade of the wheat.

During application of the dust, the air was so contaminated with dust that masks were necessary. In addition, the dust in the grain and in the air caused several breakdowns of the machinery, increased maintenance problems, and slowed grain movement.

No insects developed in either the treated or untreated wheat. Artificial infestations were made at the beginning and near the middle of the reporting period, but for reasons not known these attempts failed to produce enough of an infestation to be detectable.

The dust treatments reduced the test weight of the wheat considerably and also reduced its commercial grade. The reduction of test weight apparently did not affect the flour-yielding capacity. The moisture content remained almost constant throughout the period.

In the bioassay tests, consistently greater mortalities were recorded for rice weevil adults than for lesser grain borer adults. In all tests, however, the effectiveness of the treatment was reduced by the end of the reporting period. There was very little difference in bioassay results with Perma-Guard®, Kenite® 2-I, Dri-Die® SG-68, and malathion. Mortalities from Cab-O-Sil® were much less in the 12-month samples.

The bread-baking properties of the wheat were apparently unaffected by the treatments used in this test.

BACKGROUND AND PURPOSE OF THE WORK

The concept of using inert dust to control stored-grain insects is not new. Before tests were begun in 1963 to evaluate four inert dusts as grain protectants under field conditions, a review was made of previous investigations by the Stored-Product Insects Research Branch into the use of inert dust for the protection of stored grain. Most of the information has not been published. The first work was conducted in 1938 by R. T. Cotton and George B. Wagner, who

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reported on the use of Naaki, a finely ground quartz of about 98 percent silicon. They placed flour beetles, rice weevils, lesser grain borers, and cadelles in 16-percent moisture wheat. Four samples were treated with Naaki at 1 percent by weight, and one sample was untreated. They found more insects in the untreated sample after 84 days, but the treated samples also contained enormous numbers of insects.

T. F. Winburn and R. T. Cotton reported in 1939 that Aridite, an activated pyrophyllite, when used at the rate of 1 pound to each bushel of grain, failed to give adequate protection. The experiments were conducted in 16-percent moisture wheat held at 80°F.

Other tests were conducted in 1939 by R. T. Cotton, G. B. Wagner, and T. F. Winburn (5). These tests involved borax, soybean flour, sulfur, lime, and wood ashes. They concluded that all the materials except borax failed to give adequate protection in 16-percent moisture wheat. The tests showed good protection in 10- and 12-percent moisture wheat. Borax appeared to have excellent protective capacity, but it was absorbed into the grain and could not be recommended.

In 1941 several seed disinfectants were checked for insecticidal activity. One was an inert material, copper dust. This work by Cotton and Wagner showed that none of the materials, when used at dosages recommended for disinfecting, had any insecticidal action.

In 1942 A. I. Balzer experimented with many of the previously mentioned materials as protectants for rough rice. None of them effectively protected the rice. Besides the chemically active materials, the tests included borax, lime, magnesium oxide, and pyrophyllite. Balzer also found that in 1944, Almicide, an aluminum oxide, gave complete protection from rice weevil, lesser grain borer, flour beetles, and Indian-meal moth when applied to 14-percent moisture wheat at 0.1 percent by weight and held at 80°F. and at 40 to 50 percent relative humidity. Laboratory tests by R. T. Cotton and J. C. Frankenfeld confirmed these observations, but tests on a field scale at Hutchinson, Kans., indicated that the dust was not effective in protecting bulk wheat in storage. Infestation developed within 7 months after treatment, at which time the moisture content was about 12.2 percent.

In 1944 Cotton and Frankenfeld arranged to mill some wheat treated with aluminum oxide. They found that the milled products from treated wheat did not consistently contain a greater quantity of Al_2O_3 than the products from untreated wheat. However, samples of the treated wheat were downgraded as "treated wheat" when they were submitted to the Grain Inspection Service. Also, in 1944, they found that 0.2 percent by weight of Almicide on rough rice gave complete protection. Concurrently with these other tests in 1944, they tested a sample of magnesium oxide with a mean particle diameter of less than 0.25 micron. This material at the rate of 0.1 percent by weight quickly freed infested samples of wheat from all insect life, and no emergence occurred.

Cotton and Frankenfeld conducted many studies on inert dusts (2, 3, 4, 8). In one series they tested the repellent properties and effect on germination of magnesium oxide and aluminum oxide. They reported that both the dusts had excellent repellent properties. In the germination tests it was proven that the dusts did not reduce viability of 12-, 14-, and 16-percent moisture wheat. In fact, a slight increase in percent germination was observed. In 1945, Frankenfeld reported that after 12 months' storage following treatment, wheat treated with magnesium oxide and aluminum oxide had no loss of viability.

Some milling and baking tests in 1945 with wheat treated at 0.1 percent by weight of magnesium oxide showed no significant effect on baking quality.

Several additional materials were used in treating a variety of seeds. The inert materials were used alone and in mixtures with DDT and methoxychlor. When used alone, precipitated silica at 0.2 percent gave good kills on 12-percent moisture wheat but gave considerably lower kills as the moisture went up to 14 percent. Sunflower seeds treated with magnesium oxide at 0.2 percent by weight were completely protected for 1 year.

Similarly, wheat, sorghum, barley, and oats were treated with various dusts in 1945. When they were examined, all treated seeds were in perfect condition, regardless of the dust used or the rate of application. The dusts involved were magnesium oxide, aluminum oxide, and pyrophyllite.

The successful use of magnesium oxide for protecting seed from insect attack prompted Cotton and Frankenfeld to conduct a series of tests in 1946 in which various combinations of dusts, insecticides, and fungicides were used. Rice weevils and flour beetles were placed in treated and untreated wheat of 12- and 14-percent moisture. The insecticidal action of the combinations of magnesium oxide and various fungicides was satisfactory.

Attaclay, a clay of 1-micron particle size, was tested by treating 12- and 15-percent moisture wheat at dosages of 1 and 2 ounces per bushel. This work was also done by Cotton and Frankenfeld in 1946. Rice weevils and flour beetles were used as test insects. The effect of the clay was like that of other inert dusts--it protected low-moisture grain but lost some of its effectiveness at higher moisture levels.

In a test designed to reveal any differences in behavior between activated and nonactivated magnesium oxide, various samples of light, medium, and heavy oxides were used to treat 12- and 14-percent moisture wheat. Rice weevils and confused flour beetles were introduced into the treated and untreated test lots. Cotton reported that activation did not increase the insecticidal value. However, voluminosity was correlated with insecticidal action, since the light magnesium oxides were effective at lower dosages than the heavy oxides.

Late in 1946, five diatomaceous earths and garnet dust were used as test materials for treating 12- and 14-percent moisture wheat. Rice weevils and flour beetles were the test insects. The diatomaceous earths were identified only by code numbers. The diatomaceous earths at a dosage of 1 part of 2,000 by weight caused death of the rice weevil and flour beetle adults in a comparatively short time. The flour beetles did not reproduce. Very few rice weevils emerged in the 12-percent moisture wheat, but a considerable number did in the 14-percent moisture wheat. Cotton and Frankenfeld also pointed out that garnet dust, while effective against the rice weevil, was completely ineffective against the flour beetle.

Since earlier tests had shown silica gel to have good insecticidal properties on seed, it was applied to animal feeds in 1946. Of the various silica gels tested, Santocel C gave 100 percent kill in 1 week at 1 part per 100 and silica gel bulky powder was least effective, because it required 8 weeks to accomplish 100 percent kill at the same dosage.

In 1946 Cotton and Frankenfeld tested the differences between types of clay and brands of silica gel other than those that had previously been used. Six different types of silica gel and three types of clay were applied to 14-percent moisture wheat at a dosage of 0.05 percent. Results of the test showed all six brands of silica gel to be as effective as the silica gel bulky powder previously used. The clays were equally as effective as the silica gels but not so rapid in action. In the first test, rice weevils were used and in the second, granary weevils. Identical results were obtained.

Continuing the inert material tests into 1947, Cotton and Frankenfeld tested the effectiveness of two brands of silica gel on canary food. The treated samples were held at 80° F., after flour beetle adults and Indian-meal moth larvae had been introduced as test insects. Of the two gels, Santocel C at 1 percent by weight was most effective.

Cotton and Frankenfeld also tested silica gel in water suspension on 14-percent moisture wheat against granary weevils and confused flour beetles. Formulating the silica gel in water greatly reduced its efficiency.

Silica gel was used by H. H. Walkden and G. D. White in 1947 to topdress farm-stored wheat in wooden bins whose walls had been treated with DDT and methoxychlor. Treatments were evaluated on the basis of the number of living insects found in the grain over a period of several months. The silica gel grain surface treatment did not add to the effectiveness of the overall treatment.

In 1948 J. C. Frankenfeld and J. K. Quinlan began some tests using larger samples of test wheat. They treated 2,000-gram lots of 14-percent moisture wheat and held them for 2 months at 80° F. Silica gel (Santocel C) at 1,000 and 2,000 p.p.m. and magnesium oxide at 500, 1,000, and 2,000 p.p.m. failed to prevent infestation.

Simulated bin studies of 28 pounds of fumigated shelled corn in 1-cu.-ft. masonite bins were made by D. W. La Hue and Oliver Kendrick. Celite, magnesium oxide, and Santocel C

were each applied at 0.05 percent by weight. None of the three materials were completely effective, although Celite and magnesium oxide were much better than Santocel C.

D. W. La Hue, G. H. Spitler, and Oliver Kendrick reported on similar tests in 1950. In these tests 20 pounds of oats, heavily infested with Angoumois grain moth, were placed in cardboard drums. Treatments were made with magnesium oxide at 1 percent, Santocel C at 0.5 percent, and Celite at 0.25 percent and 1 percent. The oats treated with magnesium oxide and Celite continued to be heavily infested, but only a limited number of insects emerged from those treated with Santocel C.

Frankenfeld, in 1950, treated 1-pound lots of wheat in small burlap bags and exposed them to a heavy concentration of a variety of stored-grain insects in an infestation room. Magnesium oxide alone and with Arasan appeared to be most effective for insecticidal action. Dow magnesite, a synthetic magnesium oxide, and bauxite fines had a definite repellent action. However, magnesite failed to repel flour beetles, and bauxite fines were not repellent to lesser grain borers, Mediterranean flour moths, or flour beetles. Simultaneously, Frankenfeld conducted tests with 1-pound lots of shelled corn in 7-ounce burlap bags. He found all the inert dusts used, namely, bauxite, silica, and magnesium oxide, to be equally effective after 1 month against all species except the flour beetle at dosages of 1.0 and 0.5 ounce per bushel. However, after 3 months of exposure, it was noted that none of the inert dusts remained effective in preventing infestation.

A. C. Apt included magnesium oxide and silica aerogel (Santocel) in some studies in 1951. He treated kidney beans containing 14-, 15-, and 16-percent moisture, and blackeye cowpeas containing 8-, 10-, 14-, and 16-percent moisture. Test insects were adults of the common bean weevil and Southern cowpea weevil. Each lot contained 200 g. and was held at 80° F. The two dusts were applied at 0.1 percent by weight, and neither was effective at that dosage.

In an exploratory, nonreplicated study, R. D. Speirs in 1960 thoroughly coated flour beetle adults with 11 dusts in individual tests and made mortality counts at the end of 3, 4, 5, 7, and 10 days. The results showed Dri-Die SG-67 to be much the fastest acting of the dusts tested (this material differed from the Dri-Die SG-68 because it contained ammonium fluosilicate). Cab-O-Sil, calcium phosphate, Dri-Die SG-68, Porocel 1, and Silikil eventually produced high mortalities but were much slower acting than Dri-Die SG-67. Attaclay, Attasorb, LVM, Panther Creek Clay, and Perma-Guard produced no significant mortalities.

In 1954, N. M. Dennis tested the efficiency of silica aerogel as a protectant against insect attack on skin cleanser composed of oat flour and kaolin. Addition of 1 percent silica aerogel by weight provided excellent protection. Flour beetle adults introduced into such formulations died without reproducing.

Also, in 1954, Dennis tested low-density silica dust at rates of 0.5 and 1.0 percent by weight in pancake flour against confused flour beetle adults and larvae. Both dosages were effective in arresting development of immature stages in the first month of exposure. Exposures of 2 months caused high mortalities to the introduced adults. An aged silica gel formulation was found to be ineffective.

In 1956, Dennis tested 1-percent silica aerogel and found that added to oat flour it almost eliminated infestations of adults and reduced larval populations of the confused flour beetle after 2 months. Two purified grades were found less effective.

Dennis also tested amorphous silica dust as a protectant for wheat. Applications of 2 mg. of dust per 20 g. of 12-percent moisture wheat and 24 mg. of dust per 20 g. of wheat gave almost complete kills of rice weevils and confused flour beetles with 1 week's exposure. There were no signs of reinfestation after 8 weeks. There was an adverse effect on commercial grade.

In 1958, W. Keith Whitney, Orlo K. Jantz, and Leon H. Hendricks tested the effects of silica gel-oat flour formulations on the development, mortality, and reproduction of the confused flour beetle. Formulations containing 1- and 2-percent silica gel had very little effect on the mortality or reproduction of the confused flour beetle. Adult test insects were more susceptible than last-instar larvae.

A number of other researchers in the United States and other countries have recently contributed to the study of these materials.

The field study reported here has not yet been completed. The primary objective was to determine the relative ability of two basic types of chemically inert dust to control insect infestation and to prevent subsequent reinfestation of stored wheat by stored-grain insects. Secondary objectives of this test were to determine the effect of the dust deposit upon the commercial grade and the bread-baking quality of the treated wheat.

TECHNIQUE AND MATERIALS

Equipment and Handling Procedures

A 30-bin experimental series using chemically inert dusts as a means of protection against insect attack was begun in September 1963. The site of the test was the ASCS Binsite at McPherson, Kans., where sufficient wheat (90,000 bushels) of one crop year was available on a single site. The wheat was of the 1952 crop year and in good condition. The moisture content of the wheat was expectedly low--none of the bins exceeded 11.4 percent moisture in 1963.

The wheat had been treated several years before with calcium cyanide, and the dust of spent material was evident in the bins. There was evidence also of previous infestation by various insect species, especially lesser grain borer, cadelle, and Indian-meal moth. There was no general living infestation in the bins at the time of treatment.

Prior to treatment, samples of wheat were taken from the bins and bioassayed at the Manhattan laboratory. The bioassay tests indicated that the 1952-crop-year wheat under laboratory conditions supported insect development and reproduction equally as well as 1-year-old untreated wheat.

Each of 30 standard circular 3,250-bushel metal bins of the McPherson ASCS Binsite was filled with wheat to the 2,800-bushel level to facilitate later probing operations.

Moving the bulk of the wheat from one bin to another required the use of two grain augers. The first auger had a barrel 18 feet in length and 5 inches in diameter, powered by a 1-cylinder gasoline engine. The second auger was 30 feet long, with a barrel diameter of 8 inches. It was powered by a 2-cylinder gasoline engine. Both of these augers were equipped with wheels and could be moved about. When the grain level in the bin was such that grain would no longer flow from the bin into the first auger, a third auger was employed. This consisted of a gasoline engine mounted on a channel-iron frame which was set in the frame of the bottom bin door. This apparatus was fitted with a free auger-helix on a universal knuckle joint. This unit moved the grain from the bottom of the bin with a minimum of hand scooping.

The wheat from the dispatch end of the first auger flowed over a 10-foot-long metal screen with about 5/64-inch openings. The screen slanted about 45°. This screening operation was used to remove the spent cyanide dust, grain dust, weed seed, and broken kernels, which resulted in a more uniform lot of wheat for test purposes.

Grain Treatment Procedures

The wheat fell from the screen into a large tractor tire casing which served as a hopper for the second larger return auger-elevator. The Perma-Guard Dust Applicator--a unit consisting of a dust hopper, an electric motor-powered screw, and a regulatory dust flow gate--was set to discharge the chemically inert dust at this point. As the lower end of the screw auger picked up the grain and dust, the two were mixed by the action of the auger. The auger-elevator then discharged the treated wheat over the distributor cone in the second bin.

Perma-Guard and Kenite 2-I were applied to five bins each at a treatment rate of 7 pounds per ton of wheat. Cab-O-Sil and Dri-Die SG-68 were applied to five bins each at a treatment rate of 1 pound per ton of wheat.

An emulsifiable concentrate of 57-percent premium-grade malathion was used as a check treatment, at a dosage of 1 pint, mixed with 5 gallons of water, per 1,000 bushels of wheat. The spray was introduced through a hole on the upper side of the barrel about 1 foot from the pickup end of the 30-foot auger.

The malathion spray unit was a simple electric-driven impeller-type pump equipped with bypass and pressure regulation assembly.

Since the nozzle was practically inside the auger, there was no spray drift. The action of the auger and the distributor mixed the spray with the wheat. The binned grain was dry to the touch. Five bins of wheat were treated with malathion to provide a standard for treatment comparison.

To insure identical grain handling procedure, the five bins of untreated check wheat were turned in the same manner as the treated wheat.

Materials

The following insecticidal materials were used: Perma-Guard, Kenite 2-I, Cab-O-Sil M-5, Dri-Die SG-68, and malathion. The two diatomaceous earths, Perma-Guard and Kenite 2-I, were finely divided, naturally occurring minerals. The two silica aerogels, Cab-O-Sil and SG-68, were manufactured silica dusts.

The malathion formulation was the premium-grade 57-percent malathion emulsifiable concentrate. The other materials had the following properties, as listed by their manufacturers at the time of purchase. No attempt was made to analyze the materials at this laboratory.

Perma-Guard:

Moisture...percent..	1.5 to 3.0
Dry density...lb. per cu. ft..	20.0 to 24.0
Retained on 325-mesh screen...percent..	9.0 to 13.0
Particle size...microns..	.1 to 40.0
Silica (SiO_2), guaranteed...percent..	Minimum 80.0
Cristobalite...do..	Maximum 1.0
Surface area...$cm.^2$ per g.	20,000 to 30,000
Brightness...photovolt..	60 to 75

Kenite 2-I:

Moisture...percent..	8
Dry density...lb. per cu. ft..	min. 14, max. 15
Retained on 200-mesh screen...percent..	Less than 3
Retained on 325-mesh screen...do..	Less than 10
Silica (SiO_2)...do..	88
Surface area...sq. cm. per g..	30,000
Brightness...photovolt..	70
pH (approx.)...	7

Cab-O-Sil:

Free moisture (105° C.)...percent..	0.2 to 1.5
Apparent bulk density:	
Fluffy grade...lb. per cu. ft..	2.5 to 3.5
Densed grade...do..	6.5 to 7.0
Bulking value...gal. per lb..	0.057
Particle size range...microns..	0.015 to 0.020

Cab-O-Sil:

Silica (SiO_2)....percent..	99.0 to 99.7
Surface area....sq. meters per g..	175 to 200
pH....	3.5 to 4.0
Color....	White
Refractive index....	1.55
Specific gravity....	2.1

SG-68:

Free moisture (105° C.)....percent..	4.0
Bulk density....lb. per cu. ft..	5
Particle size:	
Average....microns..	3.5
Range....do..	80 percent less than 5.5
Silica (SiO_2)....percent..	99.+
Surface area....sq. m. per g..	300
pH (5 percent dispersion)....	7.4
Color....	White
Refractive index....	1.46
Specific gravity....	2.1

Bin Infestation Procedures

To simulate the treatment of insect-infested wheat, insects were added at regular intervals to the wheat as it fell into the hopper from the screen. Every bin in the test was infested with approximately 1,000 of each of the following: Rice weevil adults, immature rice weevils, lesser grain borer adults, and saw-toothed grain beetle adults.

OBSERVATIONS DURING TREATMENT

Effect on Personnel

The operators had to wear respirators when working near the treatment and handling of grain with dusts. At no time did the workers suffer any ill effects as a result of handling the dusts.

Effect on Machinery

When either of the diatomaceous earths was applied, an auger power loss was apparent, but there was no real problem of increased power demands as long as the grain flow was regulated to about 600 bushels per hour. The malathion-treated and untreated (check) grain was turned at a rate of 900 to 1,000 bushels per hour.

Treatment with silica aerogel, however, did damage the equipment. A flow rate of 500 bushels per hour with the same augers could not be maintained. The engines would falter and even stop when the augers became impacted with grain. When attempts were made to free the augers of the impacted grain, the clutch burned out. The fiber facings on the clutch plate wore

completely off and were ground up in the clutch housing oil bath. The main clutch plate was forcibly twisted and cracked. Had the clutch not burned out, it would have torn out and probably caused more damage.

On another occasion, one of the engines began to lose power and would not move the grain. It was noted that the oil bath filter in the air intake of the engine had effectively removed the dust (most of which was silica gel) from the air. When enough silica aerogel had been absorbed by the oil, it congealed into a fairly solid gel, thus cutting the engine off. Therefore, the engine oil baths had to be cleaned after only 3 or 4 days of operation instead of the recommended 7 days.

OBSERVATIONS AFTER TREATMENT

Monthly Observations

At monthly intervals after treatment, probe samples were taken with a standard 5-foot grain trier. The wheat samples were taken at the center top, center middle, center bottom, and the four compass points near the bin wall. The samples were put in envelopes and taken to the laboratory, where they were observed for moisture content and insect infestation. The moisture content of the wheat was uniformly low, ranging from 10.2 to 11.4 throughout the test period.

These observations indicated that insect populations failed to develop, even in the untreated check series. In an effort to promote the development of insects to evaluate the relative effectiveness of the treatments, insects were introduced for the second time in all of the bins.

In June 1964, about 3,000 individuals of lesser grain borers and rice weevils were placed with a pipe into the top 3 feet of grain in each bin. Placement was about 1 foot from the bin walls (temperature 80° F.). The insects were located "off the probing quadrants" so that the infestation would not be picked up in subsequent monthly probings.

About 800 lesser grain borers, 800 rice weevils, and 100 saw-toothed grain beetles were scattered over the surface of the grain (temperature 92° F.) in each bin. Two-hundred saw-toothed grain beetles were also probed into the upper 3 feet of the grain. Since the insects had been in the culture grain for several days before they were used, there was an immature infestation in that grain, also.

Subsequent monthly observations to date have failed to reveal insect populations large enough to evaluate the effectiveness of the treatments.

Repellency

Immediately after treatment and at 3-month intervals thereafter, samples of the treated wheat were taken to the laboratory and tested for repellency to insects.

These tests were conducted at the Manhattan laboratory, using a modification of the Laudani-Swank Laboratory Repellency Testing Apparatus (7).[4] Adult rice weevils were used as the test insects.

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[4] Berndt, Wayne L. Synergism in the Repellent Action of Combinations of Piperonyl Butoxide and Allethrin. (Unpub. Ph. D. thesis). Kansas State University, Manhattan, Kans. 1963.

Table 1.--Repellency of treated wheat toward rice weevils over a period of 12 months after treatment

Treatment	Repellency after interval of--				
	1 month	3 months	6 months	9 months	12 months
	Percent	Percent	Percent	Percent	Percent
Perma-Guard....................	85.6	87.8	81.1	93.0	79.0
Kenite 2-I....................	90.0	91.0	78.4	94.2	88.5
SG-68.........................	62.3	75.5	59.8	90.4	64.2
Cab-O-Sil.....................	71.1	69.8	57.5	82.2	58.7
Malathion (standard)..........	8.0	29.4	12.9	2.7	-15.6

As shown in table 1, all four of the chemically inert dusts exhibited considerable repellency toward the test insects throughout the 12-month period. The repellency values achieved by the two silica aerogels were not as high as those of the diatomaceous earths.

Slight repellency was exhibited by the malathion-treated wheat only for the first 9 months.

Bioassay Tests

Wheat samples taken from the bins every 3 months were bioassayed in the laboratory at 80° F. and at 60 percent relative humidity to determine the effect of the treatments on the mortality of adult test insects and the extent of progeny production.

Three 250-gram portions of wheat from each bin were placed in jars and subjected to infestation by adult rice weevils and lesser grain borers and the immature stages of the rice weevil. After an exposure period of 21 days, the adult insects were removed and mortality records made. The wheat was then held for an incubation period of an additional 42 days, when progeny counts and mortality were recorded.

The immature stages of the rice weevil were added to the wheat samples by supplying wheat containing immature forms of known age (3 weeks). After an exposure period of 56 days, the number of emerged adults, live and dead, was recorded. Table 2 is a summary of bioassay test data.

All of the treatments were more effective in controlling rice weevil adults than lesser grain borer adults. Considerably more rice weevil progeny developed in the 12-month samples than in the 1-month through 9-month samples. There was no consistent pattern to the emergence of lesser grain borer adults, and likewise no consistency in the mortality produced from the treatments.

When immature rice weevils were used as test insects, a more uniform pattern was found. All treatments showed less control in the 12-month sample than they did in the 1-month sample. There was very little difference between results from the various treatments, except that those from Cab-O-Sil were considerably lower.

Table 2.--Mortality of immature and adult rice weevils and adult lesser grain borers in insecticide-treated wheat at various intervals after treatment, and number and mortality of progeny produced

Treatment and age at sampling	Immature rice weevil		Adult rice weevil			Adult lesser grain borer		
	Emerged	Mortality	Mortality	Progeny	Progeny mortality	Mortality	Progeny	Progeny mortality
	Number	Percent	Percent	Number	Percent	Percent	Number	Percent
Perma-Guard:								
1 month	153	100.00	100.00	0	--	92.82	2	100.00
3 months	81	100.00	100.00	7	100.00	97.39	164	58.53
6 months	354	85.59	100.00	16	100.00	93.67	14	100.00
9 months	305	96.06	100.00	17	100.00	87.04	83	67.46
12 months	490	67.14	100.00	104	100.00	80.04	48	79.16
Kenite 2-I:								
1 month	118	100.00	100.00	0	--	93.42	12	100.00
3 months	169	100.00	100.00	5	100.00	97.13	66	60.60
6 months	324	96.91	100.00	4	100.00	90.40	14	92.85
9 months	270	96.29	91.59	8	100.00	100.00	115	80.00
12 months	475	87.78	100.00	155	100.00	80.09	54	70.37
SG-68:								
1 month	125	99.20	98.33	215	80.00	76.05	9	0.00
3 months	79	100.00	100.00	10	100.00	83.09	39	64.10
6 months	498	29.71	98.80	48	33.33	96.88	9	88.88
9 months	312	80.76	100.00	18	100.00	87.74	87	35.63
12 months	541	79.85	100.00	208	84.13	80.65	20	50.00
Cab-O-Sil:								
1 month	177	100.00	99.20	35	100.00	85.82	2	50.00
3 months	108	100.00	100.00	327	100.00	81.96	91	56.04
6 months	467	49.89	100.00	94	50.00	96.45	12	83.33
9 months	257	93.38	100.00	22	90.90	92.54	78	34.61
12 months	523	28.29	87.14	1009	16.15	36.00	72	15.27
Malathion (standard):								
1 month	64	100.00	100.00	2	100.00	93.02	4	100.00
3 months	125	100.00	100.00	22	100.00	97.55	7	100.00
6 months	281	98.93	100.00	30	100.00	100.00	10	100.00
9 months	251	90.43	100.00	71	100.00	87.34	10	80.00
12 months	536	78.54	100.00	696	91.52	63.67	26	50.00
Check (untreated):								
1 month	82	4.87	1.63	3341	1.26	27.50	156	5.13
3 months	154	0.00	8.67	1296	8.25	9.21	415	31.33
6 months	513	8.77	6.46	2259	5.66	28.63	229	24.01
9 months	665	1.35	4.08	4448	3.39	13.02	3643	2.63
12 months	529	1.89	0.80	6102	0.50	20.49	126	2.38

Chemical Analyses

At the beginning of the test, samples of untreated wheat were analyzed for malathion residue. None was found within the 0.5 p.p.m. sensitivity of the analytical method.

Samples of wheat were drawn from the malathion-treated series of bins at 3-month intervals after treatment for residue analyses. The results are shown in table 3.

The malathion was retained very well, probably because of the low moisture content of the grain. One month after application the average residue was 7 p.p.m. and at 12 months it was 5.5 p.p.m.

Commercial Grade

At the beginning of the test, a composite was taken from 15 probe samples of wheat throughout each bin, both before and after treatment, and submitted to the USDA Grain Inspection Office in Kansas City, Mo., for official grade determinations. This was done again 1 year after treatment. Table 4 lists the test weight and moisture content of the wheat.

The test weight of the inert-dust-treated wheat was appreciably reduced by treatment in all bins. The test weight of wheat averaged 3.2 pounds per bushel less after treatment with diatomaceous earth than it was just before treatment. Wheat treated with silica aerogel lost an average of 3.3 pounds per bushel.

Commercial grade factors responsible for the original grade and subsequent grade changes of the samples of wheat taken from the test bins are shown in table 5. Grain grading standards were revised, effective June 1, 1964. Consequently, the 1-year-after-treatment samples were graded under the revised standards.

Lowered test weight was the predominant factor responsible for reducing the grade of wheat treated with the dusts. Malathion-treated and untreated (check) wheat were downgraded primarily on the basis of foreign material and total defects.

Table 3.--Malathion residues on wheat from 1-month and quarterly samplings of 5 malathion-treated bins at McPherson, Kans.

Bin number	Malathion residue recovered after--				
	1 month	3 months	6 months	9 months	12 months
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
A..................	6.9	7.0	9.4	8.3	4.7
B..................	7.5	6.9	8.0	7.3	6.0
C..................	6.1	7.0	9.2	7.7	5.6
D..................	5.9	6.0	7.5	7.1	5.6
E..................	8.6	4.9	7.1	4.7	5.6
Average............	7.0	6.3	8.2	7.0	5.5
Check (untreated)..	< .5	--	.7	< .5	< .5

Table 4.--Average and range of test weights and moisture contents of insecticide-treated wheat before and after treatment

Treatment	Before treatment		After treatment		1 year after treatment	
	Average	Range	Average	Range	Average	Range
TEST WEIGHT:	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Perma-Guard......	59.8	58.7 to 60.2	56.7	55.7 to 57.5	56.8	56.0 to 57.5
Kenite 2-I.......	59.8	59.2 to 60.8	56.5	56.1 to 57.0	56.6	56.2 to 57.0
SG-68............	59.5	59.0 to 60.0	56.4	56.1 to 56.7	57.2	56.2 to 60.3
Cab-O-Sil........	59.4	57.4 to 60.3	55.9	53.8 to 56.6	56.1	53.3 to 57.7
Malathion (standard)...........	60.2	59.3 to 60.5	60.2	60.0 to 60.5	60.1	59.5 to 60.6
No treatment.....	60.3	60.0 to 60.6	60.4	60.0 to 60.7	60.2	60.0 to 60.6
MOISTURE CONTENT:	Percent	Percent	Percent	Percent	Percent	Percent
Perma-Guard......	10.9	10.7 to 11.2	10.5	10.3 to 10.7	10.7	10.4 to 11.0
Kenite 2-I.......	10.8	10.7 to 11.0	10.4	10.2 to 10.7	10.6	10.4 to 10.9
SG-68............	10.8	10.7 to 11.0	10.4	10.3 to 10.5	10.6	10.4 to 10.7
Cab-O- Sil.......	10.8	10.2 to 11.4	10.5	10.2 to 10.8	10.5	10.3 to 10.9
Malathion (standard)...........	10.9	10.7 to 11.3	10.9	10.5 to 11.3	11.1	10.9 to 11.2
No treatment.....	10.8	10.5 to 11.0	10.7	10.5 to 10.9	10.9	10.7 to 11.0

The wheat was of uniformly low moisture content, ranging from 10.2 to 11.4 throughout the test period. There was noticeable reduction in the recorded moisture of the wheat immediately after treatment with inert dust. This reduction was generally about 0.3 percent or slightly more. The inert dust treatments of the wheat may have changed the "nestling" qualities of the wheat, which would affect the electrical conductivity of the sample, resulting in a slightly erroneous reading on the Motomco Moisture Meter, the unit used in moisture determination. In the laboratory, the addition of inert dust to the wheat immediately reduced the moisture recordings on the Motomco Moisture Meter. A method of correcting for this weight loss is described by Johnson and Kozak (6).

Milling and Baking Tests

Chemical, milling, baking, and physical dough properties of the wheat have been tested to determine what effect, if any, the different insecticide materials and storage have had on these properties.

Fourteen-pound samples of wheat were taken in a manner to be representative of the whole bin from each of four bins in all six test series just after treatment. The same procedure was followed 6 months after treatment and again 12 months after treatment. The 1-year sampling procedure, however, was modified somewhat by compositing 4 pounds of wheat taken from each of four of the five bins in each of the test series. Quality tests were made on the 16-pound composite from each series. The data on the properties tested are shown in table 6.

The test weight per bushel of the wheat treated with Cab-O-Sil, SG-68, Perma-Guard, and Kenite 2-I decreased significantly (about 3.5 pounds per bushel) in comparison with the untreated (check) and malathion-treated wheat. This decrease reduced the numerical grade of these treated wheats from No. 1 to about No. 3. The reduction in test weight of four of the dust-treated wheats apparently did not affect their flour-yielding capacity.

Table 5.--Commercial grade factors responsible for grades before and after insecticide treatment of wheat

Insecticide treatment and bin number	Commercial grades[1] and factors[2]					
	Before treatment	Factor	After treatment	Factor	1 year after treatment	Factor
Perma-Guard:						
162	3HW	SB	3HW	TW	3HW	TW
173	2HW	TW	4HW	TW	3HW	TW, TDF
189	1YHW	--	3YHW	TW	3YHW	TW
706	1YHW	--	3YHW	TW	3YHW	TW, TDF
776	3YHW	SB	3YHW	TW	4YHW	TDF
Kenite 2-I:						
171	2YHW	FM	3HW	TW	3HW	TW
703	3HW	FM	3HW	TW, FM	4HW	TDF
709	2HW	TW	3HW	TW	3HW	TW, TDF
775	2YHW	TW	3YHW	TW	3YHW	TW
783	1HW	--	3HW	TW	3HW	TW, TDF
SG-68:						
701	2HW	TW	[3] 3HW	TW	[3] 3HW	TDF
704	2HW	FM	[3] 3HW	TW	[3] 3HW	TW, TDF
710	2YHW	TW	[3] 3YHW	TW	[3] 3YHW	TW, TDF
755	2HW	TW	[3] 3HW	TW	[3] 3HW	TW, TDF
773	2HW	TW	[3] 3HW	TW	[3] 3HW	TW
Cab-O-Sil:						
172	2YHW	TW	[3] 3HW	TW	[3] 3HW	TW
707	2YHW	TW	[3] 3YHW	TW	[3] 3YHW	TW, TDF
712	3DHW	TW	[3] 5DHW	TW	[3] 5DHW	TW
754	2HW	FM	[3] 3HW	TW	[3] 3HW	TW, TDF
784	3DHW	FM	[3] 3HW	TW, FM	[3] 3DHW	TW, FM
Malathion (standard):						
170	2HW	FM	2HW	FM	2HW	TW, FM, TDF
705	1HW	--	1HW	--	3HW	TDF
711	2HW	TW, FM	2HW	FM	3HW	TDF
772	[4] 3HW	FM	1HW	--	3HW	TDF
780	1YHW	--	1YHW	--	2YHW	TDF
Check (untreated):						
161	1HW	--	2HW	FM	4HW	TDF
165	2HW	FM	2HW	FM	3HW	TDF
191	1HW	--	1HW	--	3HW	TDF
751	1YHW	--	1YHW	--	2YHW	TDF
785	2HW	FM	1HW	--	3HW	TDF

[1] D = Dark; Y = Yellow; HW = Hard Winter.
[2] SB = Shrunken and broken kernels; TW = test weight; TDF = total defects; and FM = foreign material.
[3] Grade shown is grade except for unknown substance. Actual commercial grade was "Sample."
[4] Would have graded "Sample" because of stones.

Table 6.--Chemical, milling, baking and physical dough properties of wheat samples collected before insecticide treatment and 6 and 12 months after treatment (check) samples

Test factor	Insecticide treatment and time of testing								
	Perma-Guard			Kenite 2-I			Malathion check		
	Before treatment	6 months after treatment	12 months after treatment	Before treatment	6 months after treatment	12 months after treatment	Before treatment	6 months after treatment	12 months after treatment
Wheat analysis:									
Test weight[1]......lb.	56.5	56.4	56.7	56.5	56.3	56.6	59.4	60.0	60.1
Flour yield[2]......pct.	76.2	75.8	75.7	76.9	76.0	74.6	76.0	75.7	75.2
Moisture......pct.	10.4	11.5	11.0	10.2	11.4	11.3	10.3	11.3	11.2
Protein[3]......pct.	10.3	10.2	10.4	10.4	10.4	10.6	10.4	10.4	10.6
Sedimentation[3]......ml.	20	20	19	21	21	21	20	21	20
Fat acidity[4]......	46	47	46	45	46	45	46	45	48
Fat content[2]......pct.	2.03	1.90	1.96	1.94	1.92	2.02	1.93	1.90	1.94
Capacitance resistance (CR)......	12.0	21.0	17.0	12.0	20.8	17.0	7.1	17.4	14.5
Flour analysis:									
Ash[3]......pct.	.52	.52	.50	.53	.52	.50	.52	.51	.50
Diastatic activity[5]......mg.	142	151	150	140	150	144	143	149	145
Farinograph:									
Mix. tolerance......min.	6.00	6.00	8.50	8.50	6.00	7.00	8.50	8.50	10.00
Mix. peak......min.	1.50	1.75	1.50	1.50	1.25	1.50	1.50	1.25	1.50
Valorimeter......	47	48	48	48	46	49	46	47	49
Absorption......pct.	57.1	56.6	56.0	56.4	55.2	55.4	56.6	55.5	56.0
Bread-baking data:									
Rich formula (with DSM)[6]:									
Absorption......pct.	63	65	64	64	66	64	65	65	64
Dough mix. time......min.	2.81	2.75	2.50	2.75	2.75	2.50	2.62	2.69	2.75
Loaf volume......ml.	678	679	685	692	674	710	720	696	735
Crumb color......score.	76	71	75	78	80	85	81	80	85
Crumb grain......score.	79	80	75	75	79	80	78	82	85
Rich formula (without DSM)[6]:									
Loaf volume......ml.	686	640	640	672	641	615	701	672	630
Crumb color......score.	85	81	85	85	80	80	80	81	80
Crumb grain......score.	85	80	75	82	79	70	80	84	80

Test factor	Insecticide treatment and time of testing								
	SG-68			Cab-O-Sil			Check (untreated)		
	Before treatment	6 months after treatment	12 months after treatment	Before treatment	6 months after treatment	12 months after treatment	Before treatment	6 months after treatment	12 months after treatment
Wheat analysis:									
Test weight[1]......lb.	56.0	55.8	56.3	55.8	55.8	55.9	59.9	60.0	60.4
Flour yield[2]......pct.	75.7	75.0	75.2	74.4	73.5	73.6	75.4	74.3	74.2
Moisture......pct.	10.6	11.3	10.9	11.0	11.5	11.0	10.9	11.2	11.0
Protein[3]......pct.	10.5	10.6	10.6	11.4	11.5	11.4	10.5	10.6	10.8
Sedimentation[3]......ml.	20	21	22	26	26	27	21	20	22
Fat acidity[4]......	44	44	46	40	40	43	40	42	44
Fat content[2]......pct.	1.90	1.81	1.96	1.82	1.81	1.83	1.87	1.88	1.87
Capacitance resistance (CR)......	12.1	19.5	14.0	14.0	22.8	14.0	8.6	17.0	17.5
Flour analysis:									
Ash[3]......pct.	.52	.49	.50	.50	.50	.49	.50	.51	.48
Diastatic activity[5]......mg.	150	146	152	145	144	143	156	159	153
Farinograph:									
Mix. tolerance......min.	8.50	8.50	11.50	7.50	8.75	11.50	8.50	7.25	11.00
Mix. peak......min.	1.50	1.50	2.00	3.50	3.50	5.00	1.50	1.75	2.50
Valorimeter......	48	48	52	53	51	60	48	46	52
Absorption......pct.	57.3	56.4	55.7	59.1	58.4	58.0	58.1	56.8	56.0
Bread-baking data:									
Rich formula (with DSM)[6]:									
Absorption......pct.	63	64	66	65	65	66	63	64	66
Dough mix. time......min.	2.50	2.75	2.50	2.69	2.69	2.50	3.00	2.69	2.50
Loaf volume......ml.	678	678	710	727	708	725	676	689	708
Crumb color......score	81	75	85	78	76	85	89	81	75
Crumb grain......score	71	78	75	78	78	85	71	79	80
Rich formula (without DSM)[6]:									
Loaf volume......ml.	679	638	665	720	685	698	657	666	688
Crumb color......score	78	79	85	80	79	85	85	85	80
Crumb grain......score	79	75	75	86	80	85	79	81	85

1 Dockage-free. 2 Moisture-free basis. 3 14.0 pct. moisture basis. 4 Milligrams of potassium hydroxide per 100-g. sample (moisture-free basis). 5 Calculated as maltose content. Milligrams per 10-g. flour. 6 Dry skim milk.

Higher test weights (plumpness) have been considered to indicate higher flour yields from a given lot of wheat. The reduction in test weights by certain treatments may affect the grade and market value of the wheat, even though the yield of flour is not reduced. The malathion treatment, from this standpoint, seemed the most acceptable. After the wheat had been treated, its weight per bushel did not change further during the 12 months' storage.

When wheats are prepared for milling, they pass through a grain scourer where most of the insecticide dusts are removed. Any fatty constituents absorbed by the dust are removed along with it in the cleaning. The fat content was determined to see if the different insecticide materials absorbed any of the fat from the wheat kernel. Neither the inert dust nor the malathion appeared to reduce the fat content of the treated and stored samples as compared with the untreated (check) wheats.

After the grain had been through the experimental cleaner, very little of the insecticide dusts were still apparent. The large commercial equipment would perhaps do a more effective job than the smaller experimental laboratory unit.

Large commercial flour mills also wash their wheat before milling. This practice would perhaps remove nearly all of the insecticide dusts from the wheat.

The Cab-O-Sil-treated wheat stored in large bins averaged about 1.0 percent higher in wheat protein content than the control and the other insecticide-treated wheats. Two bins of the grain in the four-bin storage test averaged 13.3 and 12.2 percent, while the other two bins tested 10.0 and 10.2 percent, respectively, in protein content. This higher protein apparently did not change quality properties, except that the sedimentation values averaged about five to six points higher than the average values of the other insecticide-treated wheats.

Bread-baking properties were tested by two methods. There were no important differences in loaf volume or in color and grain of bread from the different wheats and the control sample. The 12-year-old wheat (1952 crop) was in remarkably good condition considering the time it had been in storage. The bread-baking properties of the insecticide-treated wheats did not change during the 12 months' storage.

The capacitance resistance (CR) test, a measure of deterioration in grain, showed marked changes in the wheat after 6 months' storage, but little further change at the end of 12 months' storage. The rate change was generally the same for the control as for the insecticide-treated wheat. This test is relatively new and will require more data for evaluation.

The ash content and diastatic activity (calculated as maltose content) of the flour from the insecticide-treated wheats were unchanged as compared with those of the untreated wheat. The wheat protein content, physical properties of the dough (measured by the farinograph), fat acidity, and sedimentation were other properties of the insecticide-treated wheats that did not change.

The malathion-treated wheat seemed most generally acceptable. Treatment with dust reduced the test weight per bushel and lowered the U.S. grade of the grain.

FINDINGS

Although these studies with inert dust as a protective treatment have not been completed, the following points are evident from the data collected thus far:

(1) During application, the dust was so aggravating to personnel that face masks were necessary. The dust was also very harmful to the machinery used.

(2) No data were available at the end of the first year of the test on protective qualities of treatments in bins because, even after artificial infestation, insect populations did not develop in either the treated or untreated bins.

(3) All four of the chemically inert dusts exhibited considerable repellency toward adult rice weevils in laboratory studies throughout the 12-month period. The diatomaceous earths were more repellent than the silica aerogels. Malathion-treated wheat was slightly repellent for 9 months.

(4) In laboratory bioassay tests, all the materials killed a larger percentage of the rice weevils than of the lesser grain borers. However, they killed fewer insects after 12 months than at the beginning, except for the diatomaceous earth on adult rice weevils. The same was true for mortality of progeny and mortality of immature rice weevil infestations. Malathion was about the same as the dust treatments, except for Cab-O-Sil, which killed considerably fewer insects in the 12-month samples.

(5) Chemical analyses of malathion-treated wheat showed a malathion residue of 5.9 to 8.6 p.p.m. 1 month after treatment, and 4.7 to 6.0 p.p.m. 12 months after treatment.

(6) Silica aerogels reduced the test weight of wheat an average of 3.32 pounds per bushel, and diatomaceous earths an average of 3.22 pounds per bushel.

(7) Moisture was uniformly low at the beginning of the test and continued low over the 12-month storage period.

(8) The actual commercial grade was, in most cases, lowered by the dust treatments. All of the wheat treated with inert dust was reduced to No. 3 grade or lower.

(9) In the milling and baking quality tests, the reduction in test weight of the wheat treated with inert dust did not change its flour-yielding capacity.

(10) Bread-baking properties, flour yield, protein content of the wheat, sedimentation, fat acidity, flour ash, diastatic activity, and physical property of the dough in the test series were unaffected by the treatments and remained virtually unchanged after the wheat had been stored a year.

(11) The insecticidal materials of this test did not reduce the fat content of the treated and stored wheat.

In quality, the malathion-treated wheat appeared to be most acceptable, primarily because such treatment did not reduce the test weight or grade or change the appearance of the wheat.

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